WASTEWATER PLANNING USERS GROUP

GUIDE TO THE QUALITY MODELLING OF SEWER SYSTEMS

Version 1.0 **November 2006**

WASTEWATER PLANNING USERS GROUP

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Published by Wastewater Planning Users Group

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TECHNICAL ENQUIRIES

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FOREWORD

Since Urban Pollution Management (UPM) methodologies have become established, and wastewater network designs are often based on water quality as well as hydraulic parameters, the WaPUG Committee identified the need for a guide for quality modelling of sewer systems.

During the development of this document it became clear that there are a wide range of approaches being used in the UK water industry ranging from detailed deterministic modelling of water quality parameters to the use of event mean concentration techniques and hydraulic analysis. All of these methods are acceptable in the appropriate circumstances.

The aim of this document is to provide a summary of current best practice in the UK at present and provide a framework in which to carry out sewer quality modelling. It is not the intention to replace other existing publications and this guide should be read in conjunction with the UPM manual and the WaPUG *Code of practice for the hydraulic modelling of sewer systems*(1).

Our thanks are extended to all within the industry who have had an input to the drafting of this document, either as part of the drafting committee, attending workshops or giving feedback. Without your input this document would not have been possible.

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Reference	Details	Date
1.0	First published	Nov 2006

Calibration	The process of adjusting model parameters to make a model fit with measured conditions (usually measured flows). This process should be followed by verification using a different set of data to that used in the calibration.
Verification	The process of checking a model against independent data (not previously used for calibration) to determine its accuracy. Any changes to the model should be made only where this reflects the physical state of the sewer system and not solely to make the model fit the verification data.
Force-fitting	The process of making arbitrary changes to a model to make it fit observed data and should not be undertaken. The dangers of force-fitting are described in WaPUG usernote 13.
Simplified Model	A sewer model that represent only some of the individual pipes within the sewer system. Note: This term is used differently in the UPM manual (FWR 1998).
Simple Model	A sewer model that does not represent any individual pipes, but represents the sewer system as a number of tanks in series or parallel. Each tank receives foul flows and runoff from a different sub-catchment. Note: The UPM manual (FWR 1998) uses the term simplified model for this concept.

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1. INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

This document is intended to provide guidance for the production of sewer quality models. Sewer quality models are essentially based on sewer hydraulic models, which are considered in the WaPUG *Code of Practice for the hydraulic modelling of sewer systems* (WaPUG 2003). This document does not attempt to duplicate the guidance in the hydraulic modelling code of practice, but concentrates on the issues of converting a sewer hydraulic model into a sewer quality model.

The modelling of the impact on rivers can be found in the WaPUG *River Modelling Guide* (WaPUG 1998).

Guidance on how these models fit within the framework of Urban Pollution Management can be found in the Urban Pollution Management Manual (FWR 1998).

1.2 SEWER QUALITY MODEL

1.2.1 Introduction

The starting point for all sewer quality modelling is a verified hydraulic model built to the standards described in the WaPUG *Code of practice for the hydraulic modelling of sewer systems* (WaPUG 2002). However, some aspects of these models might need to be enhanced. In particular any sewer hydraulic model to be used as the basis for sewer quality modelling should include a proper understanding of the dry weather flow including any infiltration and flow patterns at combined sewer overflows.

Sewer quality models aim to represent the transport of various pollutants through the sewer system. Some models can model the in-sewer biochemical processes, although these are not currently in common use in the UK. In order to model the movements of sediments and the pollutants that are attached to them, the models simulate the deposition of sediments, their storage in the sewer systems and their subsequent re-entrainment during storm events.

1.2.2 Representation of sediments in sewer quality models

Sediments are generally considered by the software to exist in two discrete layers; an active layer on the pipe invert in which fine sediment is stored in an un-consolidated state, readily available for transportation by the flow, and a passive layer which is used to represent more permanent deposits in the sewerage system. The processes of sediment erosion and deposition occur between the flow and the active layer. The active layer is composed of sediment particles and attached pollutants which have settled out of the flow during the dry weather (antecedent) period. This can then produce a first foul flush within the sewer if the shear stresses are subsequently sufficient to cause entrainment of the sediments.

The passive layer represents sediments that have become consolidated over a period of time. This layer can be fixed and remains unchanged during any simulation. Some models allow this to change over time through the event. The passive layer effectively acts as a constriction on the pipe's hydraulic capacity.

1.2.3 Quality Parameters

The principal quality parameters typically required for studies of intermittent discharges are Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD) and Total Ammonia. Other determinands can also be modelled.

BOD exists in two states; BOD that is attached to sediments and dissolved BOD. The principal processes that effect TSS and BOD are sediment deposition, erosion and transport. As such, TSS and BOD are the parameters that can be flushed in high concentrations from the system in wet weather events. Models generally assume that Ammonia is only present in a dissolved state and, therefore, will not exist in higher concentrations in wet weather.

Modelling software that can simulate the in-sewer biochemical processes are also able to model Dissolved Oxygen (DO) within the system.

Further information on these determinands can be found in the UPM Manual (FWR 1998) and in CIRIA Report R177 (Ainger et. al. 1998).

1.3 EXPERIENCE AND TRAINING OF STAFF

Sewer quality modelling is a complex subject and it is essential that all staff involved in the work should have received training appropriate to the tasks that they are carrying out. This guide is not intended to be a substitute for such training. Training can be as part of formal education, by in-house or external training courses, open learning or on-the-job training. Records of training should be kept.

Work should be carried out by, or under the day to day direction of an experienced sewer quality modeller who should have a detailed understanding of the following:

- operational performance requirements for urban drainage systems;
- hydraulics of flow in sewers and sewer ancillary structures;
- biochemical processes in sewers and in receiving waters;
- sediment transport processes in sewers;
- urban hydrology;
- urban pollution management;
- the assumptions in the way the software represents the behaviour of sediments and pollutants;
- methods of measurement of flow in sewers and their accuracy;
- methods of measurement of the concentrations of the various determinands in sewers and their likely accuracy;

- engineering solutions.

1.4 DOCUMENTATION

Adequate documentation should be provided so that subsequent users can fully understand the development of the models and to give confidence in the results. All modelling work should be documented to ensure that the reasons for any decisions can be identified at any time during or after the completion of the work. This is to ensure that the implications of any changes in source data, or any changes in any of the assumptions, can be easily identified. This information will also be necessary if the model is to be updated at a later date.

Details of assumptions will also be required by subsequent users to establish the applicability of the model for later use.

Further information on documentation is given in Section 7.

1.5 QUALITY SYSTEMS

The work of building a sewer quality model involves use of large amounts of data. It is recommended that a quality system is used to provide a framework for controlling this flow of data.

Quality systems can comprise only a series of procedural guidance documents covering general areas of policy such as filing, document control, document approval and issue etc.

There are clear advantages to all parties in having detailed working procedures for modelling work to maximise the use of skilled personnel while maintaining high standards of work. This guide provides basic information that can be used with a quality system to control sewer quality modelling work.

2. PROJECT DEFINITION

2.1 DEFINING THE PURPOSE OF THE MODEL

2.1.1 Introduction

As with all modelling activities, it is essential that the objectives of the modelling study are clearly defined before commencing work on a sewer quality model. This will include defining the location and nature of the information required.

Sewer quality models can be used for a number of different applications including:

- Studies of intermittent discharges to receiving waters (e.g. from combined sewer overflows or from storm tanks at sewage treatment works);

- Studies of loads discharged to sewage treatment works;

- Studies of sediment transport and deposition in sewer systems for planning cleaning activities.

2.1.2 Studies of Intermittent Discharges

Studies of intermittent discharges can be required for a number of reasons including for example:

- the impact of intermittent discharges from sewer systems on shellfisheries and bathing waters;

- the impact of intermittent discharges on the water quality in rivers;

- the impact of aesthetic pollution on receiving waters (although at present these can not be directly modelled);

- investigating the impact of trade effluent discharges.

A detailed procedure for the study of intermittent discharges from sewer systems is given in the Urban Pollution Management (UPM) Manual (FWR, 1998). The initial planning stage of the UPM manual includes a scoping study to identify the major causes of pollution within the catchment and define the type of study required.

A sewer quality model can be one of a number of models to be produced as part of a UPM planning study. The project definition for the sewer quality model will therefore form part of a UPM Scoping Statement for a UPM study that includes the need for a sewer quality model.

The results of the scoping study can, among other things, determine whether a sewer quality model is required, and if so, the extent of the catchment to be modelled and the level of detail that should be included in the model.

The scope statement will typically include:

- A list of the parties involved;
- The environmental requirements;
- The nature of the problem to be solved;
- The boundaries of the study;
- Whether a sewer quality model is required;
- Whether to use default parameters or collect site specific data to derive quality parameters.

The scope statement should indicate which determinands need to be modelled. Typically the software has the capability to model Total Suspended Solids (TSS), BOD and Total Ammonia. However, by understanding how the software models these parameters it is also possible to represent the behaviour of other determinands. Total Ammonia is usually modelled as being in solution, while BOD is usually modelled as being partially in solution and partly attached to sediments. If it is necessary to model a determinand that is not already built into the software it can often be modelled by comparing it with a determinand that is represented in a similar way. .

2.1.3 Studies of Loads Discharged to Sewage Treatment Works

The output from a sewer quality model can be used as the input to a sewage treatment works model. This can be necessary where the sewage treatment works has a significant impact on a water quality problem or for designing improvements to a sewage treatment works.

Potential uses include investigation of variations in load, the effect of trade effluents or other changes in the catchment.

2.1.4 Studies of Sediment Transport and Deposition

The sediment transport modelling capability in sewer quality modelling software can also be used to model the movement of sediments in a sewer system. This could be to investigate the likely build up of sediment in a proposed sewer, or to plan an ongoing sewer-cleaning programme in an existing system. Calibration should be undertaken by comparison with data on sediment levels found in the system. Dissolved components do not normally need to be modelled. For sewer sediment studies the software should be able to link sediment transport to hydraulics. Simple sewer quality models are not usually suitable for these applications.

2.2 TYPES OF SEWER QUALITY MODELS

2.2.1 Introduction

Sewer quality models can be classified according to a two-letter coding system as shown in Table 2.1 and Table 2.2. The classification takes into account:

- Whether the software used is just a sewer hydraulic model, or whether it is has specific sewer quality modelling capabilities;

- The basis for the dry weather flow parameter values;
- The basis for the wet weather flow parameter values.

It should be noted that some combinations are incompatible.

The parameter values may be published values from textbooks or papers, which do not relate specifically to the catchment being modelled (default values) or from data collected specifically for the catchment being modelled.

Where the software also models the in-sewer processes this should also be recorded.

Table 2.1 Classification of sewer quality models according to the basis of the dry weather flow model.

Type	Basis	Basis of parameter values	Notes
-	Hydraulic model only		Not a sewer quality model
A	Hydraulic model + Event Mean Concentrations	Model using Event Mean Concentrations.	
B	Sewer quality model	Default values from textbook or software only.	
C	Sewer quality model	Use default values initially but calibrate with existing data measured at Sewage Treatment Works or other available data.	
D	Sewer quality model	Use default values initially but calibrated with data from site-specific surveys.	

Table 2.2 Classification of sewer quality models according to the basis of the wet weather flow model.

	Basis	Basis of parameter values	Notes
-	Hydraulic model only		Not a sewer quality model
a	Hydraulic model	Model using event mean concentrations (EMCs).	EMCs may be from default values from textbook or derived from site specific data.
b	Sewer quality model	Default wash-off values from a textbook or from the software and carry out with expert review of results.	
c	Sewer quality model	Use default values initially but calibrate with data from site-specific surveys with expert review of data.	

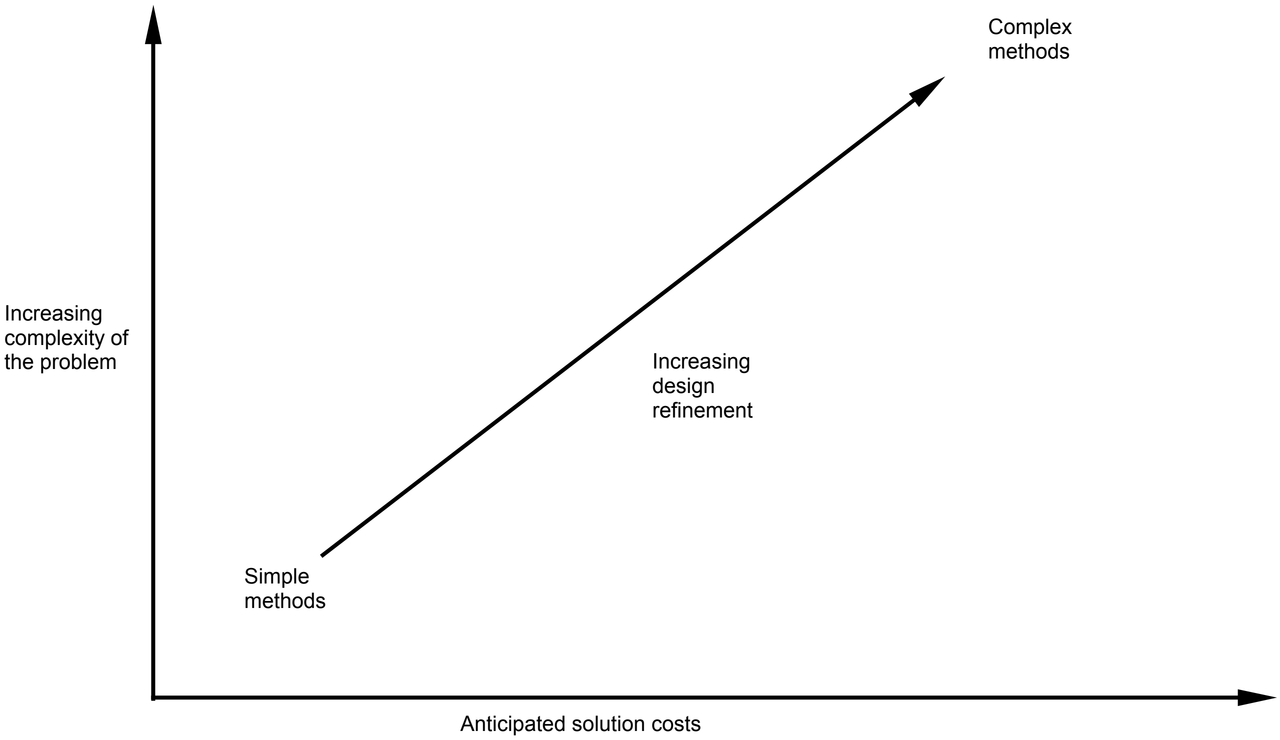
In addition, each type of model can either be based on a detailed hydraulic model (to whatever level of detail is appropriate in the circumstances (see WaPUG *Code of Practice for Hydraulic Modelling of Sewer Systems* Section 2.2 (WaPUG 2002)) or a simple hydraulic model (see the UPM Manual (FWR 1998)).

As you move from simpler methods and default values (e.g. type Aa) to more complex methods involving site specific surveys (e.g. type Dc) there should be increased confidence in the results. The more complex methods are likely to be more appropriate in cases where the anticipated solution costs are greater (see Figure 2.1).

It should be noted that simpler methods are not necessarily conservative and so where these methods are used consideration should be given to artificially increasing the values to provide more conservative results. Alternatively sensitivity analysis may be used to improve confidence.

Care should be taken in particular with first flush effects for TSS and BOD as the presence or absence of a flush can make orders of magnitude difference to peak concentrations.

Figure 2.1 Applicability of different types of sewer quality model (Based on Figure 3.2 in UPM Manual (FWR 1998))



2.2.2 Use of Hydraulic models only

For some studies a spill frequency analysis can be sufficient and it will not be necessary to use a sewer quality model at all. The only models required for this type of assessment are sewer hydraulic models of the discharges concerned.

2.2.3 Use of results from hydraulic models with event mean concentrations

The only models required for this type of assessment are sewer hydraulic models of the sewer systems concerned. The dry weather flow concentrations or event mean concentrations for wet weather flows are applied to the results of the model.

2.2.4 Other Model

Sewer quality model software differ in the calibration and calibration procedures. The pre-requisite for all such models is a verified hydraulic model of the system.

2.3 REGULATORY APPROVAL

Where regulatory approval of the final model will be required it is recommended that approval of the project definition is obtained before work continues on building the model.

3. MODEL BUILDING AND TESTING

3.1 INTRODUCTION

The basis for any sewer quality model is usually a verified hydraulic model of the system built to the standards described in the WaPUG *Code of Practice for Hydraulic Modelling of Sewer Systems* (WaPUG 2002). To be compatible with the objectives for the sewer quality model, a sewer hydraulic model should be able to predict the flows at the key points where the quality is of interest (e.g. CSO locations). If this is not the case then further work should be carried out to meet the objectives (e.g. modelling CSO spills).

The objective of the quality model is to estimate pollutant loads at the required locations during storm conditions. However, before this can be done a base dry weather quality model should be produced, capable of representing the processes (sediment/pollutant transport and deposition), which occur in the sewer and on the catchment surface during dry weather conditions.

There are three elements to a sewer quality model:

- A verified hydraulic model;
- Data to set the initial values for each determinand in dry weather flow;
- Data to set the initial values for the parameters for wet weather processes (e.g. surface wash-off, sediment erosion etc.).

3.2 VERIFIED HYDRAULIC MODEL

Data requirements for producing verified hydraulic models are given in the WaPUG *Code of Practice for Hydraulic Modelling of Sewer Systems* (WaPUG 2002).

If the hydraulic model has not been verified for dry weather flow conditions then data will be required including:

- Population figures – taking account of any seasonal variation.
- Per capita water consumption figures.
- Measured commercial water consumption figures for major users.
- Actual and consented flow rates for trade effluent discharges.
- Infiltration rates – these can vary seasonally.

CCTV data can be used to identify the locations and depths of sediment deposits in the system.

3.3 INITIAL DRY WEATHER FLOW PARAMETER VALUES

Typically the determinands used in the model are Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD) and Ammonia. The diurnal variation should be taken into account.

The quantity of pollutants attached to the sediment is typically defined by a fixed ratio referred to as the 'potency factor' (the potency factor is multiplied by the TSS concentration to provide a value for the BOD content of the sediment).

For domestic dry weather flows, values of typical dry weather quality parameters are available in the software or from other sources such as CIRIA Report R177 (Ainger et al 1998) and FR0443 (Gent et al, 1994), and should be used as a starting point. These default parameter values are representative of an average day. Where detailed calibration will not subsequently be carried out, these might need to be increased to allow for uncertainty in the model. It should be noted that these figures do not include infiltration flows, industrial or commercial flows.

For commercial flows (e.g. schools, offices, etc.) the quality is assumed to be the same as domestic flows unless data is available that indicates the contrary. The quantity can be taken from metered data.

The quality of trade effluent flows can be taken, ideally, from measured data, but failing that, from trade effluent consents. However, BOD values are not generally monitored and so these should be estimated from COD.

3.4 BASE FLOW FACTOR

The numerical solution in some software can have problems when the depth of flow is very low. Some software, therefore, does not let the depth of flow go below a set minimum. This factor should be set as low as possible as it can artificially reduce velocities and cause sediment deposition. It is recommended that this parameter is set to the minimum necessary to maintain stability.

3.5 TESTING UNDER DRY WEATHER CONDITIONS

An initial check should be carried out by running the model in dry weather conditions and checking the predictions with any available data (e.g. from sewage treatment works) to ensure the model adequately predicts the dry weather quality. If there is a substantial body of data it may be appropriate to proceed directly to the calibration stage.

The following checks should be made.

a) The load balance (inputs, outputs and changes in stored masses) should be checked.

b) The results should be reviewed to check that responses are within expected bounds, by filtering the results for unexpectedly high values (e.g. BOD values over 800 mg/l or Ammonia values above 50 mg/l).

c) Sediment accumulations should be reviewed and unexpectedly high accumulations should be reviewed.

Where mismatches are found with the concentrations of any dissolved determinands (e.g. Total Ammonia), the dry weather flow parameters should be checked to identify significant infiltration.

3.6 INITIAL WASH-OFF MODEL PARAMETER VALUES

Typical values of the wet weather wash-off quality parameters are available in the software or from other sources for example UPM Manual (FWR 1998) or FR0443 (Gent et. al. 1994), and should be used as a starting point.

The active sediment layer is made up of a number of different sediment fractions that can have different characteristics. However, as the majority of pollutants are attached to the fine sediment it is typically possible to model only the fine sediment fraction.

In the UK the Akers-White sediment transport equation is generally used. For Ackers-White each sediment fraction is defined by two parameters:

- D50 - the average sediment particle size (typically a value 0.04mm is used)
- Specific Gravity - the density of the sediment fraction (typically a value of 1.7 is used)

There are a number of different default values that have been developed based on experience, and there are no definitive values.

If typical parameter values do not reproduce the behaviour of the catchment then quality data could be collected for each determinand for a number of storm events, or adjustments made to match existing data. These should be different from any events used for calibration.

3.7 TESTING UNDER WET WEATHER CONDITIONS

The model should be run for a range of storms including storms that will initiate any first foul flush response. The start of the storm should include an antecedent dry weather flow period to allow a build up of stored sediment. For testing purposes a value of 5 days is usually sufficient. For each of the runs the following checks should be made.

a) The load balance (inputs, outputs and changes in stored masses of the effluent and each determinand) should be checked.

b) The sediment levels should be reviewed to ensure that there are no unusual accumulations of sediment in the model.

c) The results should be reviewed to check that responses are within expected bounds, by filtering the results for unexpectedly high values (e.g. BOD values over 800 mg/l or Ammonia values above 50 mg/l). Unexpected values should be reviewed to see whether they could be correct or are as a result of some error in the model. Where erroneous responses are identified these can be due to a variety of causes including:

   - Adverse gradients in the pipe data (backfalls);
   - Issues with modelling pumping stations;
   - On some software, issues with modelling steep pipes.

3.8 SIMPLE MODELS

The UPM Manual refers to the creation and use of simple models of urban sewer systems that are calibrated against detailed models. Although there is a loss of accuracy in the simplification process, there are benefits in the greater simulation speed and range of events that can be simulated. The UPM Manual (FWR, 1998) provides a specific tank-based model – SIMPOL2 – as an example of a simple model in this context.

Typically, the hydrology/hydraulics of a simple linear reservoir model would be calibrated against the results from simulating about 10 events through a verified sewer flow model (Section D.5 in UPM Manual (FWR 1998)).

For setting the quality parameters, a similar process would be used as described here – i.e. using default values and literature data appropriate for the catchment. Alternatively, if a detailed sewer quality model has been built this could be run for a small number of events to provide data against which the simple model parameters could be calibrated.

The simple model should be tested, as described earlier, to ensure that the results under dry and wet weather conditions are sensible and consistent with any available data (e.g. from sewage treatment works).

4. SITE SPECIFIC DATA COLLECTION

4.1 INTRODUCTION

As stated in Section 2, in some cases data collection will be required to provide data for model building or calibration. Section 5 of the UPM Manual (FWR 1998) gives guidance on data collection for UPM studies.

Calibration of the sewer quality model requires a series of quality data for a number of events. Data can be required for dry weather conditions and for wet weather conditions. A quality survey should be carried out. Typically this will monitor the following parameters: -

- BOD (total and dissolved);
- Total Suspended solids;
- Total Ammonia.

Some studies can require data for other parameters to be collected including:

- Physical properties of surface and in-sewer sediments;
- Chemical properties of surface and in-sewer sediments;
- Sediment depth data.

Because of the link with the hydraulic model it is strongly recommended that flow data is also collected at the same time as the quality data. Where the flow survey for verifying the hydraulic model is being carried out at the same time as the quality survey then no additional flow monitors will normally be required. However if the quality survey is being carried out at a different time then a limited number of flow monitors should be included at key points near to each quality survey.

4.2 DATA COLLECTION REQUIREMENTS

Dry weather flow calibration should use three typical events. Ideally two events should be collected during the week (24-hour mid-week events) and the third event should be collected at the weekend (48-hours). Where there are significant seasonal variations in dry weather flows it can be necessary to collect data in different seasons.

Wet weather calibration should aim to represent the response of the model in an additional three events meeting the criteria specified in the project definition in order to demonstrate that the model can fulfil its purpose. Before the survey an assessment should be carried out to determine the duration, magnitude and antecedent dry period of an event required to produce an appropriate response from the system. This could entail the use of the uncalibrated sewer quality model or a verified sewer hydraulic model of the system. For Intermittent Discharge Studies such events should be of sufficient magnitude and intensity to show a first flush response if one were to occur.

4.3 PLANNING

Information for planning sewer flow quality surveys can be found in Section 5.2 of the UPM Manual (FWR 1998). When planning the survey account should be taken of the data collection requirements for any other models being produced as part of the same UPM study.

In placing the monitors a balance should be found that targets the worst pollutant loads from overflows, as well as obtaining information on the general background quality. Normally targeting the worst pollution load or sampling the major points of interest will be the method used. Where relevant, the choice of monitoring sites should be agreed with the environmental regulator before any survey work is conducted.

The approach adopted will depend on the purpose of the model and the nature or complexity of the catchment and the areas within it.

A number of issues need to be considered in the planning of sewer quality surveys.

a) The optimum season for the work – this will depend on the objectives of the study (see project definition) and the likelihood of appropriate rainfall and receiving water conditions. Where the work is associated with a river quality survey, river levels or the temperature influences on river water quality parameters and the environmental requirements also need to be considered (e.g. where compliance with fundamental intermittent standards is the driver, the data collections should be undertaken during summer low flow conditions).

b) The parameters to be measured, and whether they can be measured with on-line monitors or whether effluent samples need to be collected for subsequent analysis. If samples need to be collected and analysed, then arrangements should be made, to store and transport the samples and for a laboratory to receive and analyse the samples within the necessary timescales.

c) If samples are being collected, the basis on which a decision will be taken to trigger the samplers at the start of an event and the mechanism for triggering the samplers need to be established. This will normally require checking weather forecasts against pre-defined criteria.

4.4 SITE SELECTION

The following factors should be considered when selecting sites for quality monitoring:

a) Accessibility – Access will normally be required 24 hours a day 7 days a week. Some locations, for example, in locked private compounds and in busy highways might, therefore, not be suitable.

b) Security – Some of the equipment is quite valuable, therefore, the site needs to be reasonably secure.

c) Mixing – It is important to select a suitable site to obtain accurate and consistent quality measurements. Ideally, sampling sites need to be located at or immediately downstream of points within the system where there is a good mixing of flows. This can conflict with the criteria for a good flow-monitoring site where turbulent conditions are undesirable. It can be necessary to site quality monitoring samplers at a different location to flow monitors. In these cases the flow monitoring should be carried out at the nearest suitable site.

d) Capability of equipment – there can be limits on the maximum depth of sewer particularly where samplers are being used. The need for intrinsically safe equipment should also be considered when selecting the site.

e) The minimum depth of flow at the site – equipment cannot operate below certain flow depths.

The sewer operator should also be consulted before final selection of sites to confirm that there are no operational issues that would preclude the use of a particular site.

Planning permission can be required in some areas if kiosks are being used to house equipment.

It is sometimes useful to prioritise the sites, identifying a number of critical sites where data is more important than other sites. This can be used to prioritise the programme to ensure that data is collected at these sites.

4.5 SAMPLING FREQUENCY

Where samplers are used, a sampling interval of 1 hour is typically used in dry weather surveys though a 2 hour interval is sometimes used for weekend surveys to allow the full 2 days to be collected in a single sampler (samplers typically contain 24 bottles).

For wet weather events sampling intervals of 15 minutes are typically used for the first 3 hours, to collect data on any first foul flush should it exist. Thereafter the interval is generally increased to 30 minutes.

4.6 DATA ASSESSMENT

The data should be reviewed after each event. In view of the cost of analysis this should be undertaken before samples are sent to the laboratory for analysis. This review should consider:

- Whether the event met the criteria for calibration of the model. For example, did the rainfall meet a certain threshold, or did a particular CSO spill for a certain duration; or, was the sewer flow response for a certain duration during the event.

- Whether all the equipment worked correctly and, in particular, whether data was collected at the critical sites.

- Whether the samplers were triggered early enough to catch any foul flush that might have occured.

The results should again be reviewed after analysis.

4.7 SEDIMENT SURVEYS

Sediment samples can be collected for analysis to determine catchment specific physical characteristics and ranges of sediment specific potency factors. However, because of the variability of sediments across a catchment large data sets can be required to give confidence that any variation from default values is general across the system. This can negate the benefit of carrying out the exercise.

Where sediment fraction analysis is carried out of in-sewer or surface sediments care should be taken to ensure that the fines are not washed out of any samples.

Where data is required to verify in-sewer sediment build up in the model, data can be obtained from:

a) Visual inspection of sediment levels in manholes. However these can sometimes be affected by local turbulence and might not be typical of sediment levels found more generally within the sewer length.

b) CCTV inspection of sewers. This can be used to get an overall view of the sediment levels throughout a sewer length.

5. CALIBRATION

5.1 INTRODUCTION

There is a big difference between calibration, force-fitting and verification of models.

Calibration The process of adjusting model parameters within a valid range to make a model fit observed data. This process can be followed by verification using a different set of data to that used in the calibration.

Force-fitting The process of making arbitrary changes to a model parameters to make a model fit observed data should not be undertaken. The dangers of force-fitting are described in WaPUG usernote 13.

Verification The process of checking a model against independent observed data (not previously used for calibration) to determine the reliability of the model. Any changes to the model should only be made where this reflects the observed pattern of flow and quality and physical state of the sewer system and not solely to make the model fit the verification data.

Dry weather flow calibration should be completed before commencing wet weather flow calibration.

Guidelines for sewer quality model calibration can be found in FWR Report FR0443 (Gent et al., 1994).

Note: As the availability of water quality data is limited and the cost of collection of specific data is large, it is considered unlikely that data will be used for verification under the definitions above. Hence, the process described in this document, will refer to calibration.

5.2 RUNNING THE MODEL

5.2.1 Antecedent Dry Weather Period (ADWP)

The antecedent dry weather period prior to a wet weather event is the time between the start of the event being considered and the end of the previous significant rainfall event.

The antecedent dry weather period will affect the amount of sediment build up, both on the surface and in the sewers, that could be mobilised by a rainfall event. An antecedent dry period should therefore be included at the start of the run to establish the sediment conditions when running the model with single events.

For recorded events this can be set as the actual period. However for design situations and during testing an antecedent dry period should be established which gives a typical response for the catchment.

Alternatively, a continuous series of rainfall and dry periods can be used to create steady-state conditions at the start of events.

5.3 PRESENTATION OF CALIBRATION RESULTS

When using on-line measurement techniques, the instrumentation (e.g. flow measurement) typically takes a number of readings and reports an average value, which allows a continuous series of values to be presented. These are, therefore, generally presented as a line on a graph for comparison with modelled data.

Where samplers are used, the samples are taken much less frequently and no averaging of results is possible. With a typical 15 minute or 30 minute interval it is quite possible that the actual intermediate value could have been significantly higher or lower than the values observed before and after. Lines should, therefore, not be drawn between observed concentrations.

Modelled and observed flows should be plotted on quality graphs. For wet weather results it can also be helpful to show the dry weather flow pattern and the rainfall on the same graph as the wet weather results.

5.4 DRY WEATHER CALIBRATION

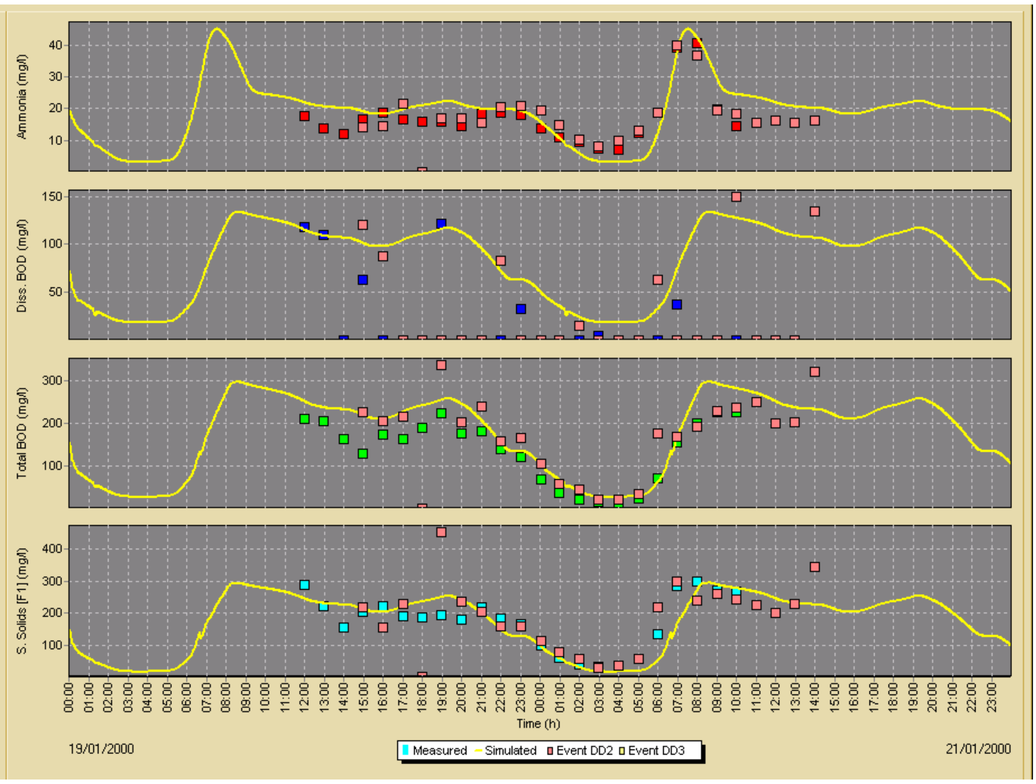
Due to the natural variability of concentrations observed in dry weather quality sampling, it would be expected that all 3 days of data would be overlaid on a single graph.

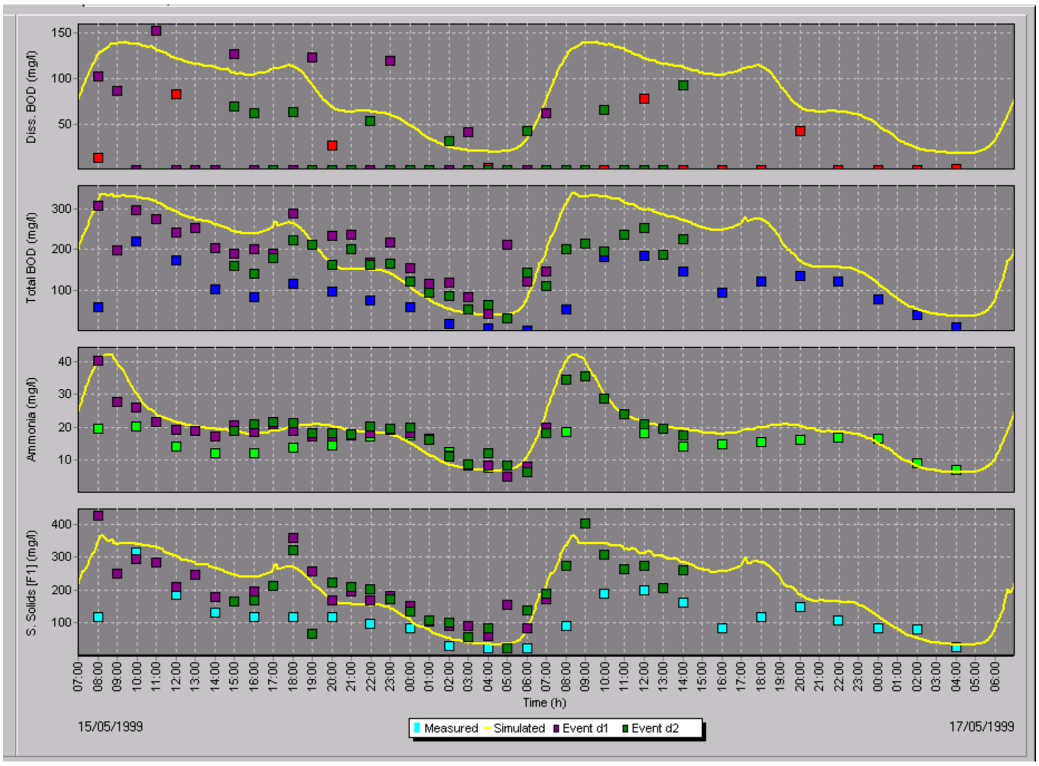
Comparisons should be made between concentrations rather than loads, as flow data can be so small during dry weather flows that monitors do not pick up good flow readings. Calculations of measured loads can, therefore, be inaccurate.

No fixed calibration criteria can be established due to the inherent variability of sewer quality processes and the limitations of data collection. The relative magnitude and timing of the observed response should nevertheless be represented.

Examples of dry weather calibration plots are shown in Figure 5.1

Figure 5.1 Examples of dry weather calibration plots





5.5 WET WEATHER CALIBRATION

Wet weather calibration should not be commenced until dry weather calibration has been completed.

The hydraulic aspects of storm flow will be covered via a conventional hydraulic verification exercise.

No fixed calibration criteria can be established due to the inherent variability of sewer quality processes and the limitations of data collection. The relative magnitude and timing of the observed response should nevertheless be represented, and the dilution in the recession limb should be matched. It is likely that a better fit can be obtained for Ammonia and other dissolved pollutants than is likely to be possible for pollutants that are bound to sediments.

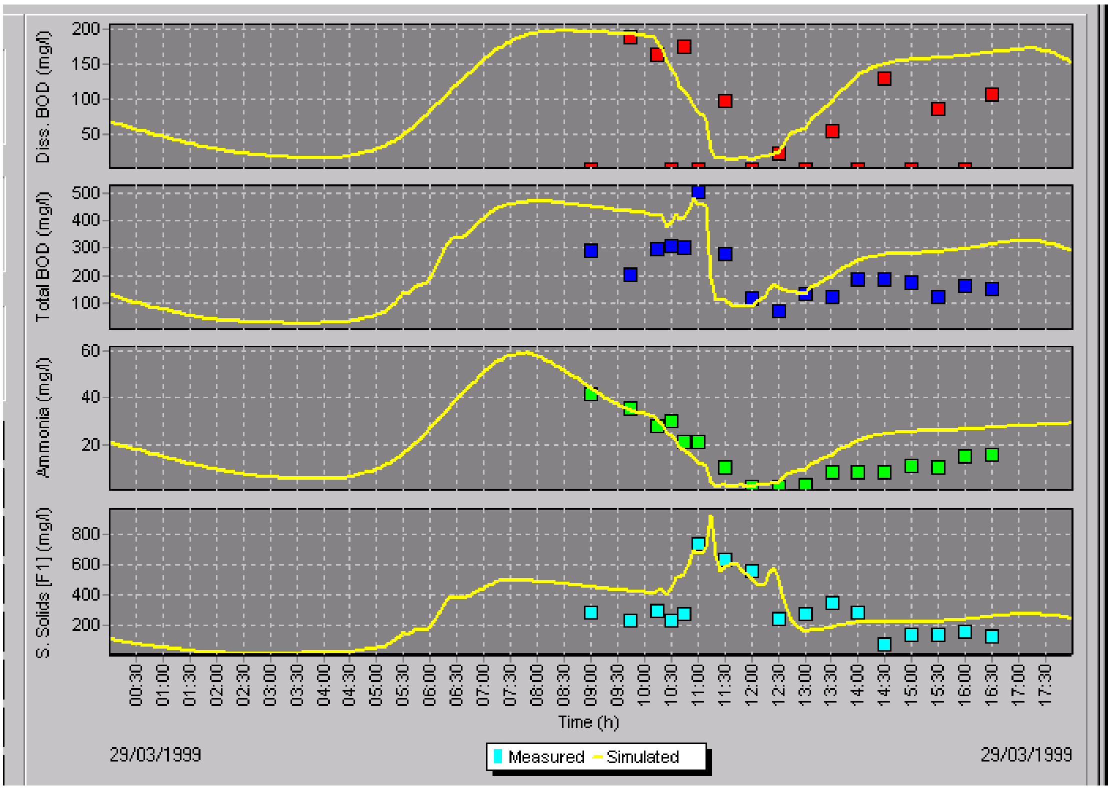
If the Ammonia values fit, any mismatch in the BOD response is therefore likely to be due to the modelling of the sediment. If the sediment levels are over predicted the pipe data should be checked for adverse gradients (backfalls) areas where there are low depths in dry weather flows which might cause modelling instabilities (see Section 3.5). In other cases the sediment parameters should be reviewed. Suspended solids inputs from traders should also be reviewed.

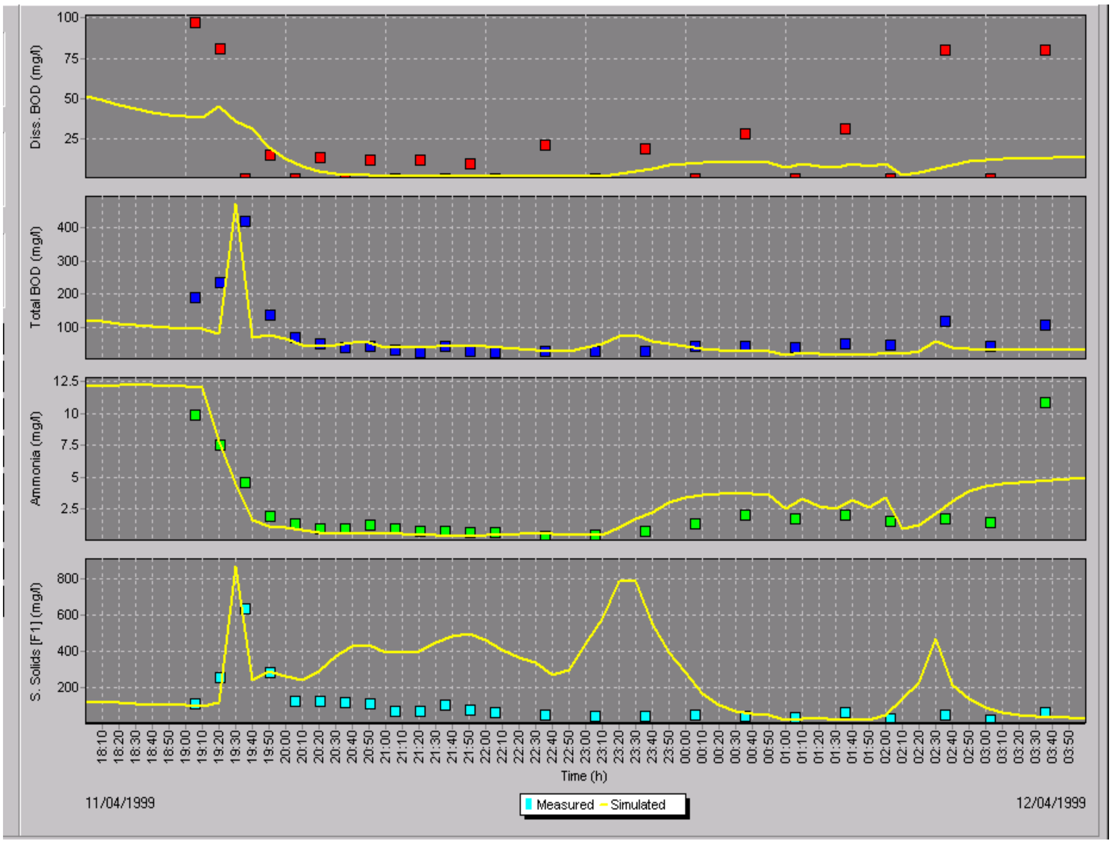
Where is not possible to calibrate the model over the entire event with the same parameter values, priority should be given to the wet weather period of the event. Where it is not possible to use the same calibration for the dry weather and wet weather conditions consideration should be given to which calibration is most appropriate having regard to the objectives of the model.

Where it is not possible to achieve a good calibration, the reasons should be investigated. In such cases, a sensitivity analysis should be carried out to establish how the model results might be used.

Examples of wet weather calibration plots are shown in Figure 5.2

Figure 5.2 Examples of Wet weather calibration plots





5.6 CALIBRATION OF SIMPLE SEWER QUALITY MODELS

At this stage, if a simple sewer quality model is being used (see Section 4.6) it would be appropriate to calibrate its quality parameters against results from a calibrated detailed model. A range of events should be used to ensure that the simple model can faithfully represent the quality performance of the detailed model.

Alternatively, it can be appropriate to directly calibrate the simple model against the catchment-specific survey data in the same way as described earlier for a detailed model.

5.7 VERIFICATION

Where additional confidence in the model is required verification of the model against another set of observed data should be considered.

6. USE OF MODELS

6.1 RUNNING THE MODEL

6.1.1 Antecedent dry period

Guidance on antecedent dry weather period is given in Section 5.2.1.

6.1.2 Time of event

The correct time of day should be included to relate the event to the diurnal dry weather flow profile.

6.1.3 Documentation

Details of all model runs should be recorded along with all associated model files. Appropriate model naming conventions should be used.

6.1.4 Model Run Time

All models should be run for a length of time to ensure that the system has drained down and all flows have reached the sewage treatment works and all CSOs have stopped spilling.

6.1.5 Routine Model Testing

The checks listed in Section 3.7 should be carried out each time the model is run.

6.2 PREPARATION OF MODEL FOR DEVELOPING UPGRADING OPTIONS

Before the model can be used to design any upgrading solutions any changes should be made to the hydraulic model as described in Section 7.3 of the WaPUG *Code of Practice for Hydraulic Modelling of Sewer Systems* (WaPUG 2002).

In addition, where there are seasonal variations in the rate of the infiltration, dry weather flow concentrations should be reviewed and the appropriate seasonal parameters incorporated in the model. This will generally be applied to the system hydraulics, but might need a change to event mean concentrations if they are being used.

Dry weather flow loads and concentrations should be reviewed and increased where planned growth within the design horizon is expected. Consideration should be given to the levels of trade effluent inputs. In particular, consideration should be given to the use of consent values for trade effluents in place of measured values.

6.3 SIMPLE MODELLING

The same procedures described earlier would also apply to the use of Simple sewer quality models. In addition, if the upgrading options being considered have resulted in significant changes to the hydraulics of the system (e.g. major changes to throttles), it will be necessary to recalibrate the hydraulics of the Simple model to match that of the detailed sewer flow model of the upgraded system.

7. DOCUMENTATION

7.1 INTRODUCTION

It is essential that the work involved in building and verifying a model is properly documented in order that future users can assess the appropriateness of a model for a particular purpose and to allow for updating and upgrading. As well as providing essential information to future users of the model, the documentation is also an essential basis for both internal and third party audits of the work. This documentation is not to be confused with the requirement from a client for a final report, which might be significantly less detailed. The following should be considered as a minimum requirement.

The main documentation should comprise four separate reports as follows.

- A model building and calibration report.
- A flow quality survey report – normally produced by the flow survey contractor.
- A verification report where verification has been carried out.
- An upgrading options report.

The document should make appropriate references to the documentation of the underlying sewer hydraulic model in order to avoid unnecessary duplication.

7.2 MODEL BUILDING AND CALIBRATION REPORT

7.2.1 Introduction

This report should contain a description of the work involved in:

- project definition;
- model building;
- model calibration;
- model testing.

The report should make appropriate references to the equivalent section of the report on the building of the underlying sewer hydraulic model.

7.2.2 Project definition

The project definition is likely to be a single scoping statement including the definition of the whole project including the sewer hydraulic modelling and any associated modelling of receiving waters.

a) A summary - outlining the purpose, methodology and the main conclusions.

b) An introduction - giving the background to the study and why it was commissioned.

c) The purpose for which the model is intended and the type of model built and any constraints. This can include a copy of any detailed client's brief.

d) A description of the existing system, area, population, types of catchment, ground, topography, significant trade effluent sources, condition of system, silting etc.

7.2.3 Data collection

The report should reference the sources of all the data used in the calibration of the various quality parameters used in the model.

7.2.4 Model Building

The model building report should include:

a) Assumptions about data.

b) A table of parameter values used.

c) Any changes made to the sewer hydraulic model in the light of the quality modelling requirements.

d) Details of the addition of the quantity and quality of trade effluent discharges included in the model and why any others were not included;

e) Details of the dry weather flow parameter values.

f) Details of the input of the wet weather model parameters including sediment data.

g) Any other relevant information.

7.2.5 Model Calibration

The model calibration report should include:

a) The source of the parameters used for the dry weather flow calibration including any trade effluent data.

b) The source of the data used for the wet weather flow calibration.

c) A list of files associated with the final calibrated version of the model.

In addition where site specific data was used in the calibration:

d) Details of the flow quality survey locations and how they were selected. The documentation should list the locations chosen and any alternatives considered. The reasons for the selection of each monitor and raingauge location should be described and their intended role in the calibration process.

e) A copy of the survey contractor's report.

f) A copy of any supplementary comments from the modeller on the performance of the quality monitoring equipment.

g) A detailed description of any changes made to the model calibration during the course of the calibration and the justification for making these changes.

h) A commentary on the final fits and a description of how well the model is considered to be calibrated. Any judgements taken or weaknesses should be itemised and any sensitivity analysis reported.

i) Copies of relevant flow quality survey and rainfall files on suitable media.

j) Conclusions - this should give an indication of the reliability of the calibration and a statement of any limitations in its potential use (i.e. design of upgrading schemes).

7.2.6 Model testing

Details of the tests carried out should be recorded. Any locations where instabilities were identified should also be recorded, together with details of the changes made to resolve them.

7.3 UPGRADING OPTIONS REPORT

This should incorporate the following.

- Details of any changes made to the verified model to take account of committed schemes and future developments etc. (see Section 6.2). This should be clearly documented. Precise details of the changes made to the model data should be supported by any calculations made and references to any source data or assumptions.

- For each option, a list of the detailed changes made to the model should be documented, supported by any calculations made and references to any source data or assumptions.

As well as the detailed description in the documentation, a note with a cross reference should also be incorporated in the comment fields in the data files.

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ACKNOWLEDGEMENTS

This draft was prepared by a Task Group of the WaPUG Committee. The Wastewater Planning User Group gratefully acknowledges the input from the following members of the task group and others who were involved in its production. Graham Squibbs – Chairman (United Utilities), Andrew Jack (United Utilities), Chris Barker (Yorkshire Water), John Hateley (Severn Trent Water), David Winter (Scottish Water), Rob Whitaker (Environment Agency), Nick Orman – Editor (WRc)

Consultation with UK water utilities, trade associations, regulators and other users was undertaken in the production and revision of this publication.

WaPUG would welcome any comments on this document which should be submitted through the WaPUG Home Page www.wapug.org.uk